

## **SP-G2 Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam**

*October 25, 2002*

### **1.0 Introduction/Background**

Dams affect downstream geomorphic processes. Most of the changes are caused by the primary function of the dam to store winter high flows and release them for irrigation and water supply during the summer. The result includes changes in yearly, monthly, and daily stream flow distribution, bankfull discharge, flow exceedance, peak flows, and other geomorphic parameters.

The reservoir also captures up to 97 percent of the clay, silt, sand, and gravel transported by the river from the watershed. Changes in sediment transport and discharge alter physical attributes and functions such as channel shape, channel stability, sediment transport and deposition, bedload recruitment, and woody debris recruitment. Channel capacity may also change, affecting flood frequency. Altered river processes may affect biological resources as well. These affected resources include coarsening of spawning gravel on riffles, changes in riparian vegetation habitat complexity and diversity, and aquatic macro-invertebrate production. Altered river processes also affect flooding, land use, recreation, and aesthetic resources.

The downstream effects of Oroville Dam are complicated by extensive stream and watershed alterations caused by other factors such as hydraulic mining, gravel mining, gold dredging, timber harvesting, water diversions, and urbanization.

Another concern is the effect of the altered hydrology on substrate scour or deposition, mobilization of sediment, and turbidity levels, both in the low flow reach and downstream of the Afterbay. Reduction in the sediment load and streamflow in the Feather River below Oroville may also affect the Sacramento River downstream of its confluence with the Feather River.

### **2.0 Study Objective**

The objective is to determine the ongoing effects of altered downstream hydrology and sediment retention in Lake Oroville on channel morphology and sediment transport below Lake Oroville. Study results will be used to identify limiting factors (impacts associated with biological effects) and develop a comprehensive sediment management plan for the purposes of protection, mitigation and enhancement measures to improve form and function in the Feather River. The study results will also be used by other studies to help assess the project's ongoing effects on downstream water quality, aquatic and riparian resources, and protection of private lands and public trust resources.

This study will determine the ongoing effect of flows on the morphology of project affected streams and project impoundments downstream of Oroville Dam. Specifically, the study will address the following components:

- 
1. Determine sediment conditions and sediment transport requirements.
  2. Evaluate sediment sources (including tributaries) and conditions.
  3. Map major sediment deposits.
  4. Evaluate stream channel stability.
  5. Evaluate project-affected sediment regimes.
  6. Evaluate timing, magnitude, and duration of project-affected flows in relation to geomorphic effects.
  7. Determine the effect of the project on fluvial geomorphologic features.
  8. Evaluate erosional effects on farmland (private and public trust resources).

### **3.0 Relationship to Relicensing/Need for Study**

A naturally functioning channel in dynamic equilibrium is capable of transporting the water and sediment delivered to it without significantly changing its geometry, streambed composition, or gradient through time. The flow conditions that promote this stability can be described as geomorphically significant flows (bankfull). These flows do the majority of the sediment transport and are considered most responsible for channel form. A natural flow regime typically includes flow ranges responsible for in-channel clearing and overbank flows to support riparian vegetation, along with channel-forming flows.

The altered sediment routing and hydrology caused by the Oroville Facilities have affected river morphology. There is a need to understand these relationships and identify potential protection, mitigation and enhancement measures.

The geomorphic investigation will compare historic and current conditions to help identify ongoing project effects to the downstream reach defined in this study. This information will be used to identify continuing project effects to downstream geomorphologic processes. It will also be used by other studies to help assess the project's effects on plant, fish, animal, and riparian resources caused by hydrologic, channel, and sediment routing changes. These data, together with other study results, will provide boundary conditions for assessing potential management actions.

Project -related structures and operations also alter flow regimes, which can impact the occurrence of geomorphically significant flows. Potential adverse effects include loss of undercut banks, increased instream fine sediment, braiding, loss of channel capacity, reduced sediment transport capability, gravel displacement, unnatural channel scour, armoring, and impairment of the ability of the stream to maintain functional riparian and instream habitat. Project-related structures and operations can also impair the stream's ability to transport the sediment delivered to it from source areas.

### **4.0 Study Area**

The study area includes the Feather River below Oroville Dam to the confluence with the Yuba River. This is assumed to be the downstream extent of observable direct affects of flow modifications. Focused studies may include selected locations including Glen Creek and along the Feather River between the confluence with the Yuba River and the confluence with the Sacramento River. Study plans approved by the Environmental Work

---

Group define the limits of the study area. If initial study results indicate that the study area should be expanded or contracted, the Environmental Work Group will discuss the basis for change and revise the study area as appropriate.

## **5.0 General Approach**

The study methodology consists of 9 individual tasks. If initial study results indicate that the methods and tasks should be modified, the Environmental Work Group will discuss the basis for change and revise the study plans as appropriate.

### **Task 1—Obtain and Review Existing Resource Data**

DWR will compile previous work using the State Resources Agency Library and extensive in-house publications. Hydrologic and cross-section data will be compiled. A set of base maps will be obtained for plotting the data.

A set of these maps is in the DWR map library. The maps show the low flow reach in great detail. An aerial photo atlas published by DWR also shows spawning riffle and cross-section locations. These will be useful for quantifying historic changes to the river channel that will be used to help quantify ongoing project effects.

Available photography will be compiled. The historical photography is a valuable resource for charting changes in stream morphology, vegetation, land use, and other data. The most recent photography will be ortho-corrected and used as a base for a Geographic Information System (GIS).

Sub-tasks and products under Task 1 include the following:

- Review of previous work will include compiling data sets, assessing the adequacy of the data, and identifying data gaps.
- Prepare a general description of the physiographic setting, including maps and descriptions of precipitation, geology, soils, topography, vegetation, and other watershed characteristics. Products will be compiled as part of the GIS database
- Compile and summarize information on large-scale geomorphic processes and disturbances within the watershed downstream of Oroville Dam. These include large flood events, volcanic eruptions, and mass movement. Information will also include human-induced events, such as deforestation, hydraulic mining, urbanization, dam building, diversions, and others.
- Identify the major sediment sources in the watershed and amount of sediment produced by the North, Middle, and South forks.
- Classify downstream reaches, using the Rosgen stream classification system. The reaches will be classified using Rosgen's Level I stream typing, then further classified using the Level II or higher classification based on channel form and substrate. The location of bank protection structures, levees, 100-year floodplain and other river data will also be collected. The results of the stream classification and data collection will be incorporated into the GIS system.

---

## Task 2—Map the Aerial Extent of Spawning Gravel Deposits

In coordination with fishery biologists, DWR will measure the actual spawning area in square feet of the riffles throughout the spawning reach. Representative areas at the head of riffles will be analyzed using bulk gravel sampling and surface sampling techniques to determine the surface and substrate quality of salmonid spawning gravel. Gradation curves for each riffle will be prepared and compared to similar investigations done in 1980, 1982, and 1997. Trend lines showing the changes in gravel size distribution will be prepared.

Subtasks and products under Task 2 include the following:

- Prepare an aerial photo atlas using recent, rectified aerial photos. These will be used as a base layer for the GIS system.
- Identify, classify, and measure the velocity, width, depth, and length of spawning habitats.
- Plot redd counts and locations (information to be obtained from fisheries study results).  
Sample and sieve gravel from the upstream end of salmonid spawning habitats. Conduct Wolman surface grid sampling at representative sieve sites. Compare and develop mathematical relation between the two sampling methods. A comparison of the Median grain size determined by the two different methods is a measure of the degree of armoring.
- Prepare tables, charts, and figures showing riffle spawning area, gravel size distribution, and spawning gravel quality. Map the spawning habitat on the atlas and the GIS.
- Locations and volumes of withdrawals and return flows to the river will be assessed for potential effects to geomorphic processes.

## Task 3—Survey Cross-Sections and Establish Photo Points

This part consists of surveying cross-section locations in the river below the dam. Cross-sections have been surveyed in the low flow reach in the past. As many of these as possible will be re-established, and additional cross-section locations surveyed to provide sufficient spacing for the study needs. Cross-sections will also be established below the Thermalito outfall, for some distance downstream and with spacing dependent on need. The end-points will be permanently marked using steel pipe set in concrete monuments and surveyed using GPS. Each cross-section location will have a photo point, and additional photo points will be established in critical areas.

Field characteristics of sediment, floodplain, and riparian condition will provide the basis for transect selection for detailed study. The study sites may include sensitive sites with potential project-related impacts, representative sites for the range of identified stream types, stream gage locations, and reference reaches.

Subtasks and products under Task 3 includes the following:

- Establish baselines, locate benchmarks and existing cross-section locations, and set monuments. Survey monuments using GPS.
- Survey cross-section locations using a tagline strung between the endpoints. Vertical measurements will be taken every ten feet and at topographic break points. The river portion will be surveyed using a small boat. The roughness coefficient and bed material size will be estimated for representative cross-sections.
- Conduct gravel sampling and intergravel permeability measurements at representative cross-sections and tabulate data.

---

#### Task 4—Monitor Cross-Section Locations and Conduct Sediment Transport Sampling

Cross-section locations will be monitored for changes periodically. A representative number will be selected to measure hydraulic and sediment transport conditions at a variety of discharges. These measurements will be used to calibrate the sediment transport and geomorphic models used in another part of the study. The monitoring will consist of setting a tag line between the cross-section monuments; measuring the depth and stream velocity; measuring bedload transport using a Helley-Smith bedload sampler; monitoring bedload movement by using painted and radio tagged rocks, measuring temperature; measuring the hydraulic radius; and other stream parameters as necessary.

Subtasks and products under Task 4 include the following:

- Select representative number of cross-section locations for monitoring.
- Conduct monitoring activities at representative low, medium, and high flows to cover the full spectrum of streamflow and sediment transport. including the evaluation of flow velocities for the initiation of bedload movement
- Measure temperature, depth, velocity, turbidity, bedload movement, and suspended sediment across the cross-section locations using standard U.S. Geological Survey methodology.
- Prepare graphs, tables, and charts showing streamflow, temperature, turbidity, sediment discharge, bedload and suspended sediment size distribution.

The assessment of channel characteristics and sediment regime observations will include:

- presence of vegetation encroachment in the low-flow channel;
- observed emergent and/or woody vegetation in low-flow, or bottom width channel;
- geomorphic function of woody debris;
- role in formation of habitat units;
- role in bed or bank definition and stability;
- verification of inventory data from the Rosgen Level 1 survey;
- evaluation of bank stability;
- identify bank stability characteristics by channel type, instability mechanism;
- bank height and length;
- alteration of channel morphology;
- field evidence of change in alignment (lateral movement, avulsion);
- observations of vertical instability (aggradation, degradation);
- observations of changes in channel dimensions (width, depth);
- excessive deposition of fine sediment;
- presence of instream bars, observation of bar size and material;
- type of depositional features associated with each channel type;
- descriptions of the features of tributary inputs;
- presence/absence of active and/or remnant deltas at confluences with main stem;
- sediment characteristics of tributary inputs: lithology, grain sizes, stratigraphy of deposits;
- length (along observed channel corridor) and estimated sediment volume;
- type of sediment (size class based on visual observation);

- 
- approximate thickness of accumulations;
  - indicators of scour and erosion;
  - comparison with reference reaches;
  - project-related sediment starving;
  - project-related structural controls;
  - dependence on channel type; and
  - functionality of riparian habitat.

#### Task 5—Determine Project Effects on River Geomorphic and Hydraulic Parameters

In this task, hydrologic analysis will be used to provide an indication of the project effects on geomorphically significant flows. Flood-frequency analysis, using hydrologic data presented in the Initial Information Package, will be applied to the Feather River to determine these flows. For alluvial systems, Andrews and Nankervis (1995) describe sediment transport and channel maintenance flows ranging between 0.8 and 1.6 times the bankfull discharge in gravel-bed rivers. For gravel-bed streams in the Rocky Mountain region, this study recommended that the channel maintenance flow be provided for an average of 15 days per year. This benchmark will be applied as an initial evaluation for river reaches with alluvial (sand or gravel beds) channels. This study (SP-G2) will also attempt to quantify riparian and valley-forming flows using the concepts as defined in Hill et al. (1991), as appropriate. Flood-frequency analysis will be used in conjunction with field indicators to determine bankfull flow. Methods in Hill et al. (1991) will be used to guide the assessment of the magnitude, timing, frequency, duration, and rate of change of out-of-channel flows.

Flow duration curves developed in SP-E2 and 3 will then be used to determine the timing and duration of geomorphically significant flows (indicated by the flood frequency analysis) in the project streams. The magnitude, timing, duration, frequency, and rate of change of flows will be described where gaging data is available. The data will be displayed graphically, and as exceedance tables. Comparison will be made between regulated and unregulated flows.

These data, taken together with the determination of geomorphically significant flows, will describe the effect of project operations on the occurrence of these flows. This will be done by comparing historic data with recent data. Available past cross-sectional data will be compared to those surveyed in Task 3 to determine changes in channel shape, form, and function caused by the dam. Changes in depth, width, hydraulic radius, roughness, gradient, pool-riffle-run ratio, and other hydraulic parameters will be determined.

Ongoing project effects to stream flow will be studied by using historical hydrologic data. The “Indicators of Hydrologic Alteration” (IHA) model will be run using the existing impaired flow data compared to unimpaired flow. Impaired and unimpaired flood frequency, flow duration, and mean monthly flow graphs will be prepared to show the changes.

Aerial photos and old survey maps will be used to establish the location of historic river channels. These will be used to establish the extents of the meander belt (if any). Geologic maps will be used with aerial photo interpretation to identify structural controls on river erosion and plan form.

Subtasks and products under Task 5 include the following:

- 
- Conduct IHA analyses to compare current and historic flow conditions. Describe and compare patterns of total annual precipitation and runoff. Delineate changes in base flows. Prepare graphs, tables, charts showing pre- and post dam changes in flood frequency, ramping rates, flow duration, mean monthly discharge, and others.
  - Collect existing survey, topographic, and photographic data. Plot channel locations for the years available on the atlas and the GIS. Delineate changes in channel location, islands, multiple channel areas, levees, and riprap. Determine ongoing impacts of the dam by comparing pre- and post dam bank erosion and channel migration rates, island and multiple channel formation rates, gravel bars, riffles, channel width, gradient, and other geomorphic characteristics. Prepare figures, graphs, and charts showing the changes.
  - Use Rosgen's Level I and Level II or higher stream classification systems to determine historic changes.

#### Task 6—Establish Bank Erosion Monitoring Sites

In areas where bank erosion is occurring, monitoring sites will be established to determine erosion rates and the nature of the material eroded). The eroding bank endpoints will be marked using steel pipe set in concrete monuments. Banks will be surveyed a minimum of twice yearly, once in the spring to determine amount of winter erosion, and once in the late fall to determine low flow erosion. The global positioning system technique will be used to determine bank location to the nearest 3 feet horizontally (plan view).

For all identified transects, detailed field measurements will include surveying the channel profile into the floodplain and abandoned floodplain (if present), identification of bankfull elevation, water surface slope, and the wetted perimeter at the time of measurement. Substrate material will also be documented (Wolman pebble count and laboratory grain size analysis), and bank slope would be recorded for alluvial sections. An assessment of out-of-channel flow requirements for riparian vegetation/floodplain landforms will be completed at approved transect locations. In addition, measurement of channel dimensions, indicators of sediment accumulation ( $V^*$  or other sediment accumulation indicator), quantitative analysis of flows required to initiate motion (Shields criterion), and quantitative comparison of sediment supply and transport capacity (expressed in tons/day or equivalent) will be analyzed at each site.

Subtasks and products under Task 6 include the following:

- Identify bank erosion sites using air photos, survey maps, and field inspection. Banks with noticeable erosion and banks that have eroded in the past (as identified by comparing the air photos and survey maps) will be catalogued. Ortho-rectify recent aerial photos to use as a base map for plotting bank erosion.
- Plot successive bank lines available from existing topographic and photographic data.
- Set survey benchmarks. Survey bank lines using GPS. Re-survey twice yearly during study to establish bank erosion rates.
- Prepare figures showing bank erosion sites. Compare historic bank erosion rates using figures and tables. Insert data into ArcView GIS.

#### Task 7—Channel Hydraulic and Sediment Transport Modeling

DWR will review the available models and select the model most appropriate for the conditions occurring in the study reach. The selected model will be used to estimate sediment transport parameters and compare existing and potential future channel form and sediment transport function. Model outputs will include

---

changes in channel scour and fill, bedload, roughness, cross-section, gradient, and sediment transport. Hydraulic conditions such as bottom shear stress, velocity, and wetted hydraulic radius will also be model outputs. Several bedload transport equations will be used, in order to identify the one most compatible with the Feather River. A bedload transport curve will be developed from model output data. This will allow the use of “design” flows to move gravel in the system. The curve can also be used to predict when additional gravel needs to be added to the system.

One of the main uses of the model is to determine at which flows the gravel bed begins to mobilize. This is critical in determining flow conditions that degrade spawning riffles. It is also important in designing spawning gravel rehabilitation measures. The model is a useful tool for predicting future changes caused by various hydraulic scenarios.

Model outputs will be calibrated with data from Task 4 and with painted and radio-tagged rocks. These rocks will be placed in the river in a number of selected places, and monitored through the winter season to determine at what flows the rocks begin to move. Rocks will be color-coded according to location. Radio-tagged rocks are first drilled using a rock bit then a small radio transmitter or transponder is inserted, and sealed using epoxy. A radio receiver or oscilloscope will be used periodically to monitor movement after significant flow events have occurred.

The magnitude, timing, duration, rate of change and frequency of flows will be described with hydrographs and exceedance tables. The time-scales will be those allowed by the existing data, daily, monthly, hourly, or in 15-minute increments. A series of tables will also be generated from the streamflow gaging data including: monthly flow statistics tables summarizing mean monthly flow and monthly exceedance flows; tables summarizing average monthly flow; tables summarizing mean daily flow for each year of the period of record; duration curves depicting the median flow for each station.

Subtasks and products under Task 7 include the following:

- Select most appropriate model(s) from the numerous available.
- Collect data and insert into model.
- Calibrate model using sediment and hydraulic monitoring data collected under Task 4.
- Run model to determine future changes. Conduct hydraulic simulations to determine initial gravel bed motion, sediment transport rates, channel changes (aggradation or degradation), slope change, bed armoring, etc.
- Document major assumptions used in the modeling.

## **6.0 Results and Products/Deliverables**

The study will be used to identify the hydraulic, geomorphic, and sediment transport changes that have occurred. The effect of these changes on salmonid spawning riffles, flooding, riparian vegetation, riparian habitat, and river habitat will be assessed. Changes in sediment transport will be evaluated for various proposed flow regimes. Based on the results of the study, we will identify needs for protection, mitigation or enhancement activities. The study results will also be used by other studies to help assess the project's

---

ongoing effects on downstream water quality, aquatic and riparian resources, and protection of private lands and public trust resources.

#### Task 8—Submit Draft Report

- The draft report will allow for comments, corrections, and additional data in preparation of the final report and will include:
- Executive Summary
- Table of Contents
- List of Tables
- List of Figures
- Introduction
- Approach
- Narratives of relevant findings by task
- Discussion addressing most relevant questions (see above) and indicating any complications/data concerns
- Conclusions related to study plan goals and objectives
- References
- Appendices

#### Task 9—Prepare Final Report

The final report will include the main report with an introduction, previous work, procedures, description of work done, results, summary, conclusions, and recommendations. A river atlas will also be prepared with recent photography, ortho- corrected, at a scale of 1 inch = 500 feet. Locations of riffles, pools, runs, spawning areas, cross-sections, monuments, sample areas, photo points, and other data will be shown. The collected data will be compiled into a Geographic Information System (GIS) database. This will allow the data to be presented in both atlas and electronic form. The GIS will also allow additional information to be added and presented at a later date.

GIS using ArcView will also be prepared with the same data. This will allow the data to be presented in both atlas and electronic form. The GIS will also allow additional information to be added and presented at a later date.

## **7.0 Coordination and Implementation Strategy**

### ***Coordination with Other Resource Areas/Studies***

It is anticipated that this study will require coordination with those individuals and agencies responsible for collecting water quality, flow data, temperature, fishery, habitat, cultural resource, recreation, and project operation data, and performing biological surveys, and fishery studies.

Implementation of this study plan will require coordination with other Oroville relicensing studies, as follows: historic air photos, riparian habitat mapping and occurrence data (SP-T4); Effects on Riparian Resources (SP-T5), Effects on Anadromous Fish (SP-F10). Historical and alternative operations data will be obtained from (SP-E2), and the Flood Study (SP-E3). This study will also require coordination with the GIS program.

---

This study fully or partially addresses the following Stakeholder issues:

*Stakeholder issues fully addressed by SP-G2 Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*

- GE3—alterations in stream hydrology affect the natural fluvial geomorphologic processes of a riverine system. How has the change in magnitude, frequency and timing of peak flows and rates of flow change on the Feather River affected riparian vegetation recruitment in the low-flow reach and immediately downstream of the Afterbay, under wet and dry year criteria
- GE4—under existing conditions, are bankfull flows frequent enough to maintain channel morphology, sediment transport, habitat diversity and adequate gravels for salmonid spawning and rearing in the low-flow section and in the river downstream of Thermalito Afterbay
- GE7—are the present streamflows defined under the SWP Feather River Flow Constraints adequate for maintaining natural fluvial river functions in the low-flow section and in the river downstream of Thermalito Afterbay (i.e., diversity of habitats: pool to riffle ratios, pool depth, stream bank angle, stream bank stability, stream bank vegetative cover, bedload deposition pattern, and stream bank vegetation root depth versus stream bank height above bankfull height)
- GE9—channel morphology and changes from operation – armoring spawning habitat and lateral erosion of banks
- GE10—has the project resulted in sediment starvation (e.g., reduced gravel recruitment) to the lower river, and if so, by how much
- GE12—river flows through low-flow sections (historically 1,600 cfs, now 600 cfs) have changed—what is the effect on channel morphology, physical processes and biological habitat
- GE19—gravel recruitment impacts of the dam – both up and down stream
- GE24—direct, indirect, and cumulative impacts of project facilities and operations on sediment movement and deposition, river geometry, and channel characteristics. This includes impacts on stream competence, capacity, bank stability and extend, duration, and repetition of high flow events
- GE25—natural geomorphologic processes historically occurred within the Feather River watershed and are the result of geologic and hydrologic processes such as weathering, erosion, runoff patterns, material transport and deposition. Project features and operations have altered these natural geomorphic processes. Alteration of these geomorphic processes has affected the riverine habitat and species that depend on it. The FWS is concerned that project operations may have taken us beyond some critical thresholds for ecosystem sustainability. We are concerned that maintenance of a satisfactory abiotic template (e.g., substrate used for invertebrate production and fish spawning) is not occurring). The FWS wants assurance that new license conditions will allow for minimum thresholds of geomorphic processes to take place thus ensuring sufficient natural sediment movement and a satisfactory abiotic habitat template are in place

*Stakeholder issues partially addressed by SP-G2 Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*

- GE5—under existing conditions, are the moderate winter floods and bankfull flows adequately recruiting the amount of large woody debris needed to maintain adequate salmonid rearing habitat in the low-flow section and in the river downstream of Thermalito Afterbay

- 
- GE6—how will the future demand for project water change the timing and duration of moderate winter floods and bankfull flows in the low-flow section and in the river downstream of Thermalito Afterbay
  - GE23—releases that reflect nature cycles benefit biological cycles—how have changes in seasonal release patterns affected fish, invertebrates, and their habitat
  - F1—effects of existing and future project operations (including power generation, water storage, ramping rates, and releases, pump-back, water levels, and water level fluctuations) during all water year types on the behavior (e.g., migration timing, microhabitat selection, vulnerability to predators), reproduction, survival and habitat of warm- and cold-water fish and other aquatic resources (e.g., macroinvertebrates), which include in project waters and tributaries within the project boundaries (Lake Oroville, Diversion Pool, Fish Barrier Pool, Forebay, Afterbay, Oroville Wildlife Area), and in project affected waters
  - F6—effects of existing and future project operations on sediment deposition, erosion, and recruitment through the system (including downstream sediment supply) and associated changes in water quality on the quantity and quality of aquatic habitats within project affected waters
  - F10—effect of existing and future project facilities and operations on Anadromous Fish habitat and populations (e.g., instream flows, water temperature, ramping rates, riparian habitat, large woody debris, predation, spawning gravels, stranding and desiccation, macroinvertebrate prey base, upstream and downstream passage, rearing conditions)
  - F11—compliance of project operations with SWP Feather River Flow Constraints and adequacy of constraints to protect Anadromous Fish and other aquatic species in the low-flow section and in the river downstream of the Afterbay
  - F13—project effects on fish species listed for protection under the California and/or federal Endangered Species Acts (ESA), species of special concern, candidate species, proposed, and likely listed threatened and/or endangered fish species, and the habitat needed to support them;
  - FE9—use Instream Flow Incremental Methodology (IFIM) or a comparable methodology to determine streamflow needs to ensure that trout habitat quality and quantity are not reduced within project area and/or project affected areas
  - FE11—Inventory streams, streamside areas, and other wetlands in deteriorating condition and restore on a priority basis within project area and/or project affected areas;
  - FE14—provide for fish passage and maintain natural channel character at stream crossings within project area and/or project-affected areas
  - FE33—are the present streamflows defined under the State Water Projects Feather River Flow Constraints being met and are they adequately protecting steelhead and fall, late-fall, and spring-run Chinook salmon in the low-flow section and in the river downstream of Thermalito Afterbay for migrating, holding, spawning, and rearing of steelhead and fall, late-fall, and spring-run Chinook salmon
  - FE37—under existing conditions, are there adequate amounts of suitable gravel for salmonid spawning in the low-flow section and in the river downstream of Thermalito Afterbay
  - FE38—preserve natural riparian flood control abilities. Remove only those log jams or major debris accumulations that have a high potential of causing channel damage, block fish passage, or could be transported downstream by high flows and cause loss of property
  - FE39—Insure that stream alterations restore the original flow capacity while preserving the existing channel alignment
  - FE86—adequacy of current ramping rate to protect Anadromous Salmonids and conserve their habitats and forage. This includes providing a range of schedule of flows necessary to optimize habitat, stable flows during spawning and incubation of in gravel forms, flows necessary to ensure redd replacement in

---

viable areas, and flows necessary for channel forming processes, riparian habitat protection and maintenance of forage communities. This also includes impacts of flood control or other project structures or operations that act to displace individuals or their forage or destabilizes, scours, or degrades habitat

- TE58—effects of changes in the magnitude, frequency and timing of peak flows in the Feather River on riparian vegetation recruitment in the low flow reach and immediately downstream of the Afterbay
- T3—effects of existing and future project operations on floodplains and project water fluctuation zones, including soil stability, wildlife habitat and natural flood control functions, revegetation of native plant communities, and restoration opportunities (e.g., red willow planting)
- T5—project effects on riparian resources and protection and management of riparian habitat and wetlands (including vernal pools and brood ponds)

Other Issues addressed by this study plan are included in Geology Issue Statement 5, which includes the following specific Issue:

- GE2—project features and operations alter the hydrology of the system, creating the possibility for scour zones within both natural and designed channels. What effects do discharge and ramping rates have on substrate scour and the mobilization of sediments into the water column downstream?

## 8.0 Study Schedule

Gravel movement experiments will be conducted in the Fall and Winter of 2002. Cross-section surveys will be conducted from March through August of 2002. Gravel sampling and salmonid spawning riffle mapping will be accomplished during the same period. Monitoring will occur during the winter of Fall 2002- Winter 2003. Follow-up surveys will be completed in Fall 2003 if needed. Modeling will be done in the Fall of 2003. The Atlas, maps, surveys, and the GIS will be produced concurrently during the studies and should be completed by the Fall of 2003. The draft report should be done by the Fall of 2003 and the final report would be completed by Summer 2004.

## 9.0 References

Andrews, E. D. and J. M. Nankervis. 1995. Effective discharge and the design of channel maintenance flow for Gravel-bed Rivers. In: Natural and Anthropogenic Influences in Fluvial Morphology, American Geophysical Union, and Geophysical Monograph 89.

California Department of Water Resources (Delta Branch), *Establishment of Feather River Channel Characteristics*, 1965.

California Department of Water Resources (Northern District), *Feather River Spawning Gravel Baseline Study*, 1982.

Hill, M. T. and, W. S. Platts, R. L. Beschta. 1991. Ecological and Geomorphological Concepts for Instream and Out-of-Channel Flow Requirements. Rivers. 210, Volume 2, Number 1.

---

Richter B. D., Baumgartner J.V., Powell J., and Braun D.P., 1996. A method for assessing hydrologic alteration within ecosystems. *Conservation Biology*, 10, 1163-1174.

Rosgen, D. L. and H. L. Silvey. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, CO. Printed Media Companies. Minneapolis, Minnesota.

U.S. Geological Survey, *Sediment Transport in the Feather River, Lake Oroville to Yuba City, California*, 1978.